Age and Musical Expertise Influence Emotion Recognition in Music

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We investigated how age and musical expertise influence emotion recognition in music. Musically trained and untrained participants from two age cohorts, young and middle-aged adults ($N = 80$), were presented with music excerpts expressing happiness, peacefulness, sadness, and fear/threat. Participants rated how much each excerpt expressed the four emotions on 10-point scales. The intended emotions were consistently perceived, but responses varied across groups. Advancing age was associated with selective decrements in the recognition of sadness and fear/threat, a finding consistent with previous research (Lima & Castro, 2011a); the recognition of happiness and peacefulness remained stable. Years of music training were associated with enhanced recognition accuracy. These effects were independent of domain-general cognitive abilities and personality traits, but they were echoed in differences in how efficiently music structural cues (e.g., tempo, mode) were relied upon. Thus, age and musical expertise are experiential factors explaining individual variability in emotion recognition in music.

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Music communicates emotions that we can recognize, enjoy, and be moved by. The cognitive and neural underpinnings of musical emotions is a topic that has attracted much recent interest (Juslin, Liljeström, Västfjäll, & Lundqvist, 2010; Juslin & Västfjäll, 2008; Koelsch, 2010; Patel, 2008; Peretz, 2010). It is known that intense pleasure responses to music engage neural systems of emotion and reward that also respond to stimuli important for biological survival, such as food and sex (Blood & Zatorre, 2001; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011). Music communicates specific emotions (e.g., happiness, sadness) as effectively as other socially prominent stimuli (e.g., speech prosody; Juslin & Laukka, 2003), and mechanisms underlying emotion recognition in music are robust and fast-acting: recognition occurs with high agreement within and between listeners (e.g., Bigand, Vieillard, Madurell, Marozeau, & Dacquet, 2005; Vieillard et al., 2008), in excerpts lasting only 250 ms (Peretz, Gagnon, & Bouchard 1998), since early childhood (Dalla Bella, Peretz, Rousseau, & Gosselin, 2001) and cross-culturally (Balkwill & Thompson, 1999; Fritz et al., 2009; Laukka, Eerola, Thingujam, Yamasaki, & Beller, 2013). In the domain of emotion processing, variability is the rule rather than the exception (e.g., Eugène et al., 2003; Hamann & Canli, 2004). However, the factors that determine variability in the context of musical emotions remain incompletely understood. That aging and music training may have a wide impact on neurocognitive and socio-emotional functions has often been sustained (e.g., Dellacherie, Roy, Hugueville, Peretz, & Samson, 2011; Habib & Besson, 2009; Hedden & Gabrieli, 2004; Hyde et al., 2009; Salthouse, 2009; Samanez-Larkin & Carstensen, 2011). In the present study we examine whether and how these factors – age and music training – modulate the recognition of musical emotions.

Aging and Emotion Recognition

A body of research, mostly on facial expressions, shows that advancing age is associated with decreased accuracy in the recognition of some emotions (e.g., Calder et al., 2003; Isaacowitz et al., 2007; Lambrecht, Kreifelts, & Wildgruber, 2012; Orgeta, 2010; Williams et al., 2009). Ruffman, Henry, Livingstone, and Phillips (2008) reviewed 17 data sets of (still) facial expressions in a meta-analysis, and concluded that older adults, around 70 years of age, are less accurate than younger ones (around 24 years) in the recognition of fear, anger, and sadness. For happiness and surprise, changes were much smaller, and for disgust there was a trend for age-related improvements. Modalities other than facial expressions are less studied, but there is evidence for age-related decrements in emotion recognition in lexical stimuli (Isaacowitz et al., 2007), body postures (Ruffman, Halberstadt, & Murray, 2009), visual scenes (St. Jacques, Dolcos, & Cabeza, 2008), and in dynamic auditory cues, namely speech prosody (e.g., Lambrecht et al., 2012; Mitchell, 2007; Mitchell, Kingston, & Bouças,

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2011) and nonverbal vocalizations (Lima, Alves, Scott, & Castro, 2013). Although typically young adults are compared with individuals aged 60 and over ("extreme age group" design; Isaacowitz & Stanley, 2011), a few studies using finer gradations in age revealed that decrements may proceed linearly with advancing age, with significant differences already in middle-age (e.g., Isaacowitz et al., 2007; Lambrecht et al., 2012; Mill, Allik, Realo, & Valk, 2009; Paulmann, Pell, & Kotz, 2008).

The mechanisms that explain these changes remain a matter of debate. One possibility is that they result from age-related cognitive and sensory losses, in domains such as attention, memory, vision, and hearing (e.g., Fozard & Gordon-Salant, 2011; Hedden & Gabrieli, 2004; Salthouse, 2009). There is some evidence, though, that these factors are poor predictors of age effects for facial expressions, speech prosody, and body postures (Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006; Lambrecht et al., 2012; Mitchell, 2007; Orbelo, Grim, Talbott, & Ross, 2005; Ruffman et al., 2008; Ryan, Murray, & Ruffman, 2010; Sullivan & Ruffman, 2004). Thus, more specific mechanisms may be involved. One hypothesis highlights the role of neural deterioration in structures implicated in emotion processing, namely in frontal and temporal lobes, and/or in neurotransmitters (Ruffman et al., 2008). The recognition of some emotions would change more than others because rates of deterioration differ across neural systems (e.g., Raz et al., 2005). An alternative hypothesis, based on the socioemotional selectivity theory, emphasizes the role of top-down controlled processing. Because of progressive reductions in perceived time horizons, aging would lead to increased prioritization of goals related to emotional well-being, resulting in increased efforts to allocate cognitive resources towards positive information and away from negative one – *positivity effect* (Carstensen & Mikels, 2005; Charles & Carstensen, 2007, 2010; Mather & Carstensen, 2005; Reed & Carstensen, 2012; Samanez-Larkin & Carstensen, 2011). Findings that age effects are smaller for the recognition of happiness as compared to negative emotions are often interpreted within this framework (Laukka & Juslin, 2007; Mill et al., 2009; Mitchell et al., 2011; Riediger, Voelkle, Ebner, & Lindenberger, 2011; Williams et al., 2006). However, the interaction between valence and age is not consistently obtained (e.g., Isaacowitz et al., 2007; Lambrecht et al., 2012; Ruffman et al., 2008). Furthermore, Cacioppo, Berntson, Bechara, Tranel, and Hawkley (2011) suggested that the positivity effect may stem not from controlled mechanisms but from automatic processes linked to deterioration in the amygdala, which would dampen responses to negative input.

To date, these causal mechanisms have been chiefly informed by evidence of facial expressions, leaving open the question of whether and how they apply to other domains. This is particularly relevant if we consider that there may be domain specificities in how age affects emotion recognition. For example, in the meta-analysis by Ruffman et al. (2008), decrements (four data sets) for anger and sadness were similar in faces and speech prosody, but for happiness they were smaller in faces than in speech, and for fear they were observed in faces but not in speech. Hence, investigating other modalities is crucial to a complete understanding of age-related changes in emotion recognition and to shed light on the mechanisms underlying these changes.

With respect to emotions expressed in music, systematic research is scant. Vieillard, Didierjean, and Maquestiaux (2012) uncovered age-related differences in valence and arousal judgments for music excerpts, indicating that age may affect how broader affective dimensions are processed. As for the explicit recognition of specific emotions, there is initial evidence of decrements for sadness and fear, both when communicated through expressive cues in performance (e.g., articulation, vibrato; Laukka & Juslin, 2007) and through variations in the compositional structure (e.g., mode, pitch range; Lima & Castro, 2011a). The recognition of positive emotions, on the other hand, may remain relatively stable (happiness, Laukka & Juslin 2007; happiness and peacefulness, Lima & Castro, 2011a). Notwithstanding, it remains unanswered whether these effects result from general cognitive and sensory losses, or can occur beyond these losses. It also remains to be determined whether the interaction between age and valence (positivity effect) is a robust finding.

Musical Expertise and Emotion Recognition in Music

Longitudinal and cross-sectional studies show that music training influences cognitive processing and brain morphology (for reviews, Habib & Besson, 2009; Herholz & Zatorre, 2012). For instance, Hyde et al. (2009) found that 15 months of music lessons in early childhood lead to behavioral improvements in melodic and rhythmic discrimination tasks and structural changes in auditory and motor brain areas. Gaser and Schlaug (2003) reported that adult professional musicians, compared to amateur musicians and nonmusicians, had increased grey matter volume in primary motor and somatosensory areas, premotor areas, anterior superior parietal areas, inferior temporal gyrus, cerebellum, Heschl's gyrus, and inferior frontal gyrus. It has also been reported that music training improves non-musical cognitive abilities, such as pitch discrimination in speech (e.g., Moreno et al., 2009), nonverbal reasoning (Forgeard, Winner, Norton, & Schlaug, 2008), and executive control (Bialystok & DePape, 2009; Moreno et al., 2011). It appears plausible, then, that music training would also improve mechanisms related to musical emotions since it affords multiple opportunities to finely differentiate emotional expressions through music. This hypothesis has intuitive appeal, but specifying which music-related abilities would be enhanced in musicians is not a trivial matter in light of evidence showing that naive listeners perform as well as experts in some music tasks – we acquire sophisticated musical knowledge just through exposure (Bigand & Poulin-Charronnat, 2006). Indeed, Bigand et al. (2005) suggested that emotional responses to music are similar in musically trained and untrained listeners. They asked participants to group musical excerpts according to the emotion that was evoked, and the number of groups produced was independent of training. The only effect of musical expertise was enhancing the consistency of responses across testing sessions in a test-retest situation (the task was repeated twice). However, this study examined musical emotions at an implicit level, and explicit tasks might be more sensitive to expertise effects (Bigand & Poulin-Charronnat, 2006). Studies using explicit tasks, though, are rare. In the study we conducted on aging and emotion recognition in music (Lima & Castro, 2011a), a subset of participants ($n = 33$ in 114) had some degree of music training ($M = 5.1$ years), and an exploratory analysis uncovered a positive correlation between this training and accuracy in categorizing emotions. A similar correlation was found by Livingstone, Muhlberger, Brown, and Thompson (2010) for music excerpts conveying emotions through both structural and expressive cues (but $n = 9$). Bhatara, Tirovolas, Duan, Levy, and Levitin (2011) also found that music training was associated with sensitivity to expressive musical cues, namely timing and amplitude ($n = 10$ in one experiment, plus $n = 10$ in another experiment). On the other hand, Resnicow, Salovey, and Repp (2004) failed to find such an effect (number of trained participants unspecified). Thus, available results are mixed and to an important extent exploratory. Furthermore, prior research did not disentangle specific effects on musical emotions from general cognitive benefits of music training (e.g., Bialystok & DePape, 2009; Schellenberg, 2006).

The Current Study

We investigated the effects of age and musical expertise on emotion recognition in music. As an extension to previous studies, we assessed general cognitive abilities and examined the extent to which these mediate age and expertise effects. Personality and socio-communicative traits were also inspected because these can influence emotion processes (Ashwin, Chapman, Colle, & Baron-Cohen, 2006; Hamann & Canli, 2004; Mill et al., 2009). Participants were younger and middle-aged musically naïve participants and expert musicians. Including middle-aged participants is a significant difference with respect to previous research. In the aging literature, the middle-years are largely neglected and this contributes to obscure continuous shifts in emotion recognition that may be significant relatively early in the adult life span (Isaacowitz & Stanley, 2011). For instance, Isaacowitz et al. (2007) found that the greatest decrements in the recognition of facial expressions and lexical stimuli occurred between younger and middle-aged participants (performance remained relatively stable afterwards). In the literature on the neurocognitive effects of musical expertise, on the other hand, most studies rely exclusively on samples of young adults. Including trained participants from two age cohorts allows for a more comprehensive and systematic examination of the role of expertise.

We used a set of music excerpts previously validated to express two positive emotions (happiness and peacefulness) and two negative ones (sadness and fear/threat) (Vieillard et al., 2008). These excerpts were composed for experimental purposes conveying emotions through structural cues, and were unknown to the participants. Participants rated how much each excerpt expressed each of the four emotions. This task does not involve selecting a single response category and so it is less prone to response biases that may affect conventional forced-choice tasks (e.g., Isaacowitz et al., 2007). Such a rating task has been widely used in experiments on emotion recognition (Adolphs, Tranel, & Damasio, 2001; Adolphs, Damasio, & Tranel, 2002; Gosselin, Peretz, Johnsen, & Adolphs, 2007; Gosselin et al., 2005; Péron et al., 2010; Sauter, Eisner, Calder, & Scott, 2010), and it was also used in the validation of the excerpts (Vieillard et al., 2008). Regarding age, considering previous studies on musical emotions, along with initial evidence that age effects are significant already in middle-age, we predicted that middle-aged participants would show decreased responsiveness to negative musical emotions, and relative stability for positive ones. Regarding expertise, we expected a correlation between length of musicians' training and sensitivity to the intended emotions, as well as an advantage of musicians over nonmusicians. If age and expertise effects are primary in their origin, they should not be reducible to differences in general cognitive and personality measures. We also conducted multiple regression analyses to investigate (a) how music structural cues predicted the listeners' ratings and (b) whether putative age and expertise effects in emotion recognition are linked to differences in how music cues are relied upon. Variations in features such as mode, tempo, pitch range, and dissonance determine the expressed musical emotions (e.g., Dalla Bella et al., 2001; Gabrielsson & Lindström, 2010; Hunter, Schellenberg, & Schimmack, 2008) and may predict subjective judgments (e.g., Balkwill & Thompson, 1999), but it remains to be determined whether the weighting of these cues varies with age and expertise.

Method

PARTICIPANTS

Eighty adults participated in the study. They were distributed into four groups of 20 participants each (10 women), varying in age (younger and middle-aged adults) and music expertise (musicians and nonmusicians). Demographic and background characteristics are shown in Table 1. Younger participants were on average 23 years old ($SD = 3.2$; range = 18 - 30) and older ones 47.7 years ($SD = 4.4$; range = 40 - 60; this age range is the one typically used in studies including middle-aged groups, e.g., Isaacowitz et al., 2007). Musicians were instrumentalists: most of them were pianists ($n = 18$), others played violin and flute ($n = 5$ in each), guitar ($n = 3$), double bass ($n = 2$), and clarinet, drums, cello, oboe, viola, trombone, and accordion ($n = 1$ in each). All underwent at least eight consecutive years of formal music training started during childhood and played their instruments regularly at the moment of testing; younger ones were advanced music students or professional musicians, and older ones were full-time music teachers and/or performers. They were recruited from professional orchestras and music schools (Orquestra Sinfónica do Porto Casa da Música, Escola Superior de Música e Artes do Espectáculo do Instituto Politécnico do Porto, Conversatório de Música do Porto). Younger and older musicians were matched in age of training onset, number of years of training, and hours of instrumental practice per week (Fs < 1; see Table 1). Nonmusicians had not had formal or informal instrumental music training and were selected from several local communities. The four groups were matched in education level, as measured in years of schooling (Fs < 1). All participants had normal or corrected-to-normal vision. In a preliminary questionnaire, none reported head trauma, substance abuse, psychiatric, or neurological illnesses. They had good hearing acuity according to self-report ($M = 2.1$; $SD = 0.9$) on a scale from 1 (*very good*) to 6 (*very bad*). No differences were found between age groups, $F(1, 76) = 1.23$, $p = .27$, partial eta-squared, $\eta_p^2 = .02$. Additionally, they rated

TABLE 1. *Characteristics of Participants by Age and Expertise Group.*

	Nonmusicians		Musicians	
Characteristics	Younger	Older	Younger	Older
Age (years)	22.7 (2.8)	47 (4)	23.4 (3.6)	48.4 (4.8)
Education (years)	15.7 (1.5)	17.1 (4)	15.4 (1.8)	16.5 (3.6)
Music training (years)	–	–	11.3 (3.1)	12.6 (3.2)
Age of training onset (years)	–	–	9.2 (2.5)	8.4 (4.5)
Instrumental practice (hours/week)	–	–	12.7 (11.6)	12.3 (11)
Montreal Cognitive Assessment (/30)	28.2 (1.3)	26.8 (1.9)	28.1 (1.6)	27.8 (1.2)
Raven's Matrices (problems solved, /36)	20.5 (4.7)	13.9 (5.1)	19.7 (4.9)	16.8 (4.5)
Stroop test[1]				
Baseline (words/s)	2.09 (0.3)	2.14 (0.3)	2.37 (0.3)	2.39 (0.3)
Incongruous condition (colors/s)	1.04 (0.2)	0.87 (0.1)	1.08 (0.2)	1.04 (0.2)
Ten-Item Personality Inventory				
Extraversion (/7)	4.8 (1.5)	4.6 (1.7)	4.8 (1)	4.9 (1.9)
Agreeableness (/7)	5.3 (0.8)	5.5 (1)	5.2 (0.9)	5.5 (0.9)
Conscientiousness (/7)	5 (1.3)	5.5 (1.3)	4.2 (1.4)	5.1 (1.5)
Emotional stability (/7)	4.2 (1.4)	4.4 (2)	3.6 (1.2)	4.5 (1.5)
Openness to experience (/7)	5.6 (0.8)	5.6 (1)	5.6 (1)	6.1 (0.9)
Autism Spectrum Quotient[2] (/50)	17.5 (5.4)	18 (4.8)	17.5 (5.7)	17.5 (5.5)

Note. Standard deviations in parentheses.
[1] Number of items named per second: number of correct responses/time taken to perform the task.
[2] Higher values indicate higher autistic-like socio-communicative traits (cut-off for clinically significant levels of autistic traits is 32).

their interest in music from 1 (*very high*) to 6 (*very low*), and musicians revealed stronger interest (1.03) than nonmusicians (2.18), $F(1, 76) = 51.94$, $p < .001$, $\eta_p^2 = .40$.

COGNITIVE AND PERSONALITY ASSESSMENT

The results of cognitive tests and personality scales are summarized in Table 1. Possible cognitive impairment was excluded with the Montreal Cognitive Assessment (MoCA; www.MoCAtest.org; Portuguese version, Simões, Firmino, Vilar, & Martins, 2007). Higher-order general nonverbal cognitive abilities were assessed with a 20-min timed version of the Raven's Advanced Progressive Matrices; this version correlates strongly with the untimed one (Hamel & Schmittmann, 2006). To examine executive control, we used a Stroop task (Trenerry, Crosson, Deboe, & Leber, 1995). Participants performed speeded naming in two conditions: baseline, consisting of reading words denoting color names (blue, *azul;* pink, *rosa;* grey, *cinza*; green, *verde*); and an incongruous condition, consisting of naming the ink of words that denoted an incongruent color name (e.g., the word "*azul,*" blue, printed in green ink; Portuguese version, Castro, Martins, & Cunha, 2003). This measure was included because music training may influence executive control, namely inhibitory abilities (Bialystok & DePape, 2009; Moreno et al., 2011; Stewart et al., 2003). Additionally, it is plausible that attention and executive control play a role for age-related differences in emotion recognition, and yet it is not usually featured in aging research (Isaacowitz & Stanley, 2011).

In the MoCA test, all participants scored within the normative range for their age ($\geq$ 25 for 25-49 years; $\geq$ 22 for 50-64 years; maximum 30), according to the norms for the Portuguese population (Freitas, Simões, Alves, & Santana, 2011). As can be seen in Table 1, musicians and nonmusicians performed similarly in this test (main effect: $F[1, 76] = 1.73$, $p = .19$, $\eta_p^2 = .02$; Expertise x Age interaction: $F[1, 76] = 2.59$, $p = .11$, $\eta_p^2 = .03$) and in Raven's matrices (main effect: $F < 1$; Expertise x Age interaction: $F[1, 76] = 2.96$, $p = .09$, $\eta_p^2 = .04$). This suggests that they were comparable in terms of general cognitive performance. In the Stroop task, musicians were faster in both baseline (main effect: $F[1, 76] = 16.43$, $p < .001$, $\eta_p^2 = .18$; Expertise x Age interaction: $F < 1$) and incongruous conditions (main effect: $F[1, 76] = 6.78$, $p = .01$, $\eta_p^2 = .08$; Expertise x Age interaction: $F[1, 76] = 2.75$, $p = .10$, $\eta_p^2 = .04$). Their advantage in the incongruous condition was reduced, and only approached significance, when baseline differences were partialed out in an ANCOVA (main effect: $F[1, 75] = 3.70$, $p = .06$, $\eta_p^2 = .05$; Expertise x Age interaction: $F[1, 75] = 2.83$, $p = .10$, $\eta_p^2 = .04$). This suggests that musicians' enhanced executive control was partly due to an advantage in processing speed. Concerning age-related differences, middle-aged musicians and nonmusicians scored lower than their younger counterparts in the MoCA test ($F[1, 76] = 5.47$, $p = .02$, $\eta_p^2 = .07$), Raven's matrices ($F[1, 76] = 19.53$, $p < .001$, $\eta_p^2 = .20$), and in the incongruous condition ($F[1, 76] = 7.70$, $p = .008$, $\eta_p^2 = .09$), but not baseline condition of the Stroop test ($F[1, 76] = 0.02$, $p = .65$, $\eta_p^2 = .00$).

As control measures for personality and socio-communicative traits we used the Ten-Item Personality Inventory (TIPI), a brief questionnaire that inspects the Big-5 personality domains: extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience (Gosling, Rentfrow, & Swann Jr., 2003; Portuguese version, Lima & Castro, 2009), and The Autism-Spectrum Quotient (AQ), a questionnaire that assesses socio-communicative traits associated with the autistic spectrum in neurotypical adults (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Portuguese version, Castro & Lima, 2009). Autistic traits correlate with structural and functional differences in brain regions involved in emotion processing (Di Martino et al., 2009; Hagen et al., 2011), as well as with behavioral differences in emotion recognition in facial expressions (Poljac, Poljac, & Wagemans, 2013), even in neurotypicals. As can be seen in Table 1, both age and expertise groups had similar personality and socio-communicative characteristics (AQ: main effects of age and expertise, both $F < 1$; Expertise x Age interaction: $F < 1$; TIPI: main effect of age: $F[1, 76] = 2.23$, $p = .08$, $\eta_p^2 = .05$; main effect of expertise: $F < 1$; Expertise x Age interaction: $F[1, 76] = 1.68$, $p = .20$, $\eta_p^2 = .02$.

MUSIC STIMULI

Stimuli were 40 instrumental music excerpts selected from the set validated by Vieillard et al. (2008). This is a set of excerpts composed in the tonal musical tradition to express four emotions: happiness, peacefulness, sadness, and fear/threat (we used 10 per emotion).[1] The excerpts consisted of a melody with accompaniment produced by a digital synthesizer in piano timbre; they

[1] The selected happy excerpts were written in a major mode, with the melodic line lying in the medium high pitch range, and they did not include pedal (metronome marking $M = 140$; range = 107 – 180); sad excerpts were written in a minor mode and were played using pedal (metronome marking $M = 47$; range = 40 – 60); fearful/threatening excerpts included minor chords on the third and sixth degree, irregular rhythms, and some of them were dissonant (metronome marking $M = 92$; range = 44 – 140); finally, peaceful excerpts were written in a major mode, and they were played using pedal and arpeggio accompaniment (metronome marking $M = 71$; range = 54 – 88).

do not vary in performance-related expressive features (e.g., dynamics, vibrato, phrasing, or articulation), and their mean duration is 12.4 s. Emotions are conveyed exclusively by compositional structure through variations in mode, dissonance, pitch range, tone density, rhythmic regularity, and tempo. Procedures used for perceptual validation (Vieillard et al., 2008) included categorization, gating, and dissimilarity judgments, and they confirmed that the intended emotions are perceived rapidly, with high accuracy and high interlistener agreement. In a cross-cultural study, Fritz et al. (2009) showed that emotions in these excerpts can be universally recognized. These excerpts have also been used in studies of patients with focal brain damage (Gosselin et al., 2005), neurodegenerative disorders (Drapeau, Gosselin, Gagnon, Peretz, & Lorrain, 2009), and neurotypical children (Hunter, Schellenberg, & Stalinski, 2011). In the present study, the selected excerpts were pseudo-randomized and divided into two blocks of 20 trials each; the presentation order of the blocks was counterbalanced across participants. Two additional excerpts were used as practice trials: for happiness, 15s from Debussy's Golliwog's Cakewalk, and for peacefulness 18 s from Rachmaninoff's 18th Variation from the Rhapsody on a Theme by Paganini.

PROCEDURE

Participants were tested individually in a single experimental session lasting about 90 min. The sessions took place in a quiet room and were conducted by a psychologist experienced in neuropsychological assessment, helped by a research assistant. After filling a brief questionnaire exploring their demographic, background, and musical profile, participants completed the tests evaluating domain-general cognitive abilities and the scales covering personality and socio-communicative traits. Concerning the emotion recognition task, they were told that they would listen to short music excerpts expressing different emotional states, namely happy (*alegre*), peaceful (*sereno*), sad (*triste*), and fearful/threatening (*assustador*). They rated how much each excerpt expressed each of the four emotions on 10-point intensity scales, from 0 (absent, *ausente*) to 9 (present, *presente*). It was stressed that for each stimulus they should respond to the four emotion scales because different emotions could be elicited simultaneously, with different or similar degrees of intensity. For instance, even if they perceived a stimulus as happy, they would have to rate it not only with respect to happiness but also with respect to sadness, fear, and peacefulness. The four scales were presented simultaneously for each stimulus and always in the same order (happy/sad/scary/peaceful). Each stimulus was presented only once and no feedback was given, including in the practice trials. The task started with the practice trials, followed by two blocks of stimuli with an interstimulus interval of 6 s. Stimulus presentation was controlled by SuperLab V4.0 software (Abboud, Schultz, & Zeitlin, 2006) running on a MacBook Pro Apple computer. Excerpts were presented via high-quality headphones adjusted to a comfortable volume level for each participant. As part of another study, they later performed a forced-choice task of emotion recognition in speech prosody (Lima & Castro, 2011b).

Results

To compare emotion recognition across groups, we derived a measure of accuracy from the raw ratings based on the emotion that received the highest rating. For each subject and excerpt, when the highest of the four ratings matched the intended emotion, the response was considered an *accurate* categorization. When the highest rating corresponded to a non-intended emotion, the response was considered *inaccurate*. When the highest rating corresponded to more than one emotion (e.g., giving 8 for sadness and also for peacefulness, and lower ratings for the other two categories), the response was considered *ambivalent*. Ambivalent responses indicate that more than one emotion was perceived with the same strength for a given excerpt. This derived measure of accuracy has been used in studies of emotion recognition in music (Gosselin et al., 2007; Gosselin et al., 2005; Vieillard et al., 2008) and in prosody (e.g., Adolphs et al., 2002). It controls for the possibility that participants of different groups used the scales differently (because it is based on relative differences between ratings on the intended and non-intended scales, rather than on absolute values), and takes into account judgments for the intended and also the non-intended emotions: a response is accurate only when the rating for the intended emotion is higher than the ratings for all the non-intended emotions.

Table 2 presents the percentage of accurate categorizations for each emotion and the distribution of inaccurate and ambivalent responses in each group. Accuracy rates were always higher for the intended than the non-intended emotions. As can be seen in the diagonal lines of Table 2 (bold cells), accuracy ranged between 42% (peacefulness in younger nonmusicians) and 96% (happiness in younger nonmusicians). This confirms that the stimuli effectively communicated the four intended emotions (in a conventional forced-choice task with five response alternatives, four emotion categories and ambivalent responses, chance-level would be 20%).

TABLE 2. ***Distribution of Responses (%) for each Intended Emotion in Younger and Older Nonmusicians and Musicians.***

Age group/ excerpt type	Responses (%)									
	Nonmusicians					Musicians				
	Happy	Peaceful	Sad	Scary	Ambivalent	Happy	Peaceful	Sad	Scary	Ambivalent
Younger										
Happy	**96 (1.3)**	1	1	0	2	**95 (2.8)**	2	0	0	4
Peaceful	14	**42 (7.3)**	27	0	18	22	**46 (7.5)**	11	0	22
Sad	0	6	**83 (3)**	3	9	0	12	**70 (6.6)**	1	18
Scary	6	0	8	**77 (4.4)**	10	2	2	15	**70 (7)**	11
Older										
Happy	**91 (3.8)**	0	3	2	4	**95 (2.3)**	1	0	1	5
Peaceful	13	**51 (5.4)**	11	3	23	12	**64 (5.7)**	12	0	13
Sad	6	20	**52 (7.1)**	1	22	1	18	**64 (5.6)**	1	17
Scary	17	2	14	**49 (5.8)**	18	8	0	11	**72 (5.5)**	10

Note. Diagonal cells in bold indicate accurate identifications, i.e., match between the highest rating and the intended emotion. In Ambivalent responses the highest rating was assigned to more than one emotion. *SE*s are presented in parentheses.

EFFECTS OF AGE AND MUSICAL EXPERTISE ON RECOGNITION ACCURACY

We first examined how age and musical expertise affected recognition accuracy. Correct categorizations per emotion were arcsine transformed and submitted to a mixed ANOVA with emotion as the repeated-measures factor (happy, peaceful, sad and scary), and age (younger and middle-age) and expertise (nonmusicians and musicians) as between-subject factors. The interaction between age, expertise, and emotion was not significant ($F[3, 228] = 1.09$, $p = .36$, $\eta_p^2 = .01$), but the interactions between age and emotion ($F[3, 228] = 7.30$, $p < .001$, $\eta_p^2 = .09$) and between age and expertise were, $F(1, 76) = 5.78$, $p = .02$, $\eta_p^2 = .07$ (Expertise x Emotion interaction: $F < 1$; main effect of age: $F[1, 76] = 2.11$, $p = .15$, $\eta_p^2 = .03$; main effect of expertise: $F[1, 76] = 2.12$, $p = .15$, $\eta_p^2 = .03$). Concerning the interaction between age and emotion, planned comparisons confirmed our predictions: older participants were less accurate than younger ones in categorizing sadness (76% for younger vs. 58% for older, $p = .01$) and fear (73% for younger vs. 60% for older, $p = .02$); in contrast, the recognition of happiness remained stable ($p = .43$), and accuracy rates for peacefulness slightly increased (44% for younger vs. 57% for older, $p = .03$). Concerning the interaction between age and expertise, because it was not predicted *a priori*, post hoc Tukey HSD tests were conducted instead of planned comparisons. These tests indicated that age-related differences were significant in nonmusicians ($p = .04$), but not in musicians ($p = .91$). They also revealed that older musicians had significantly higher accuracy (73%) than age-matched nonmusicians (61%, $p = .04$), though younger musicians and nonmusicians performed similarly (70% and 73% respectively, $p = .91$). Thus, our hypothesis that musicians would present an advantage over nonmusicians was confirmed for older participants only.[2] The pattern of age and expertise effects was replicated in ANOVAs computed on unbiased accuracy rates[3] and on the raw ratings for the intended emotions, with the exception that the age-related increase for peacefulness turned out *ns* (for the sake of completeness, the average raw ratings for each emotion and group are provided in Appendix). We also looked for possible effects of gender, but they

[2] We explored whether musicians' performance varied according to instrument played. Because these were very varied (see Method), we categorized them by group [keyboard, $n = 18$; strings, $n = 12$; woodwinds, $n = 7$; others, $n = 3$ (drums, accordion, and trombone)] and computed an ANOVA with accuracy rates as dependent measure. Performance was similar across instrument groups ($p > .10$).

[3] In forced-choice tasks, raw proportions of correct responses are not always the best measure of accuracy because they are vulnerable to response bias. Participants might be disproportionately likely to respond using some response categories rather than others. As a consequence, differences between groups might reflect this bias instead of true differences in the intended ability (for a review, see Isaacowitz et al., 2007). Our accuracy data are less prone to bias because they are derived from ratings on intensity scales and participants did not perform any choice between categories. However, to confirm that the pattern of age and expertise effects is not a by-product of possible response trends, we reanalyzed accuracy using *unbiased hit rates,* Hu (Wagner, 1993). Hu is a measure of accuracy which is insensitive to bias in responses. It represents the joint probability that a stimulus category is correctly recognized when it has been presented, and that a response is correct given that it has been used. It was calculated for each emotion and participant using the formula $Hu = A^2 / (B \times C)$, where A corresponds to the number of stimuli correctly identified, B to the number of presented stimuli (10 per category), and C to the total number of responses provided for that category (i.e., including misclassifications). Values were arcsine transformed before being analyzed.

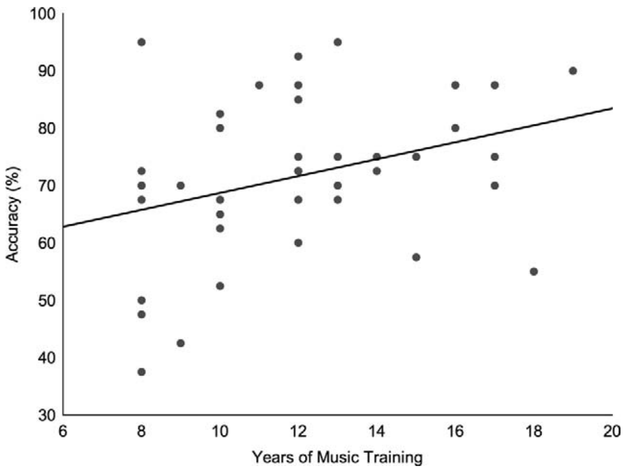

FIGURE 1. Correlation between years of musical practice and accuracy in the recognition of emotions in music.

were *ns* (main effect of gender, $F < 1$; interactions with age, expertise, and emotion, all *p*s > .08).

To further explore the developmental trajectories of the four emotions, we computed Pearson correlations between age in years and categorization accuracy for each emotion. These analyses were calculated separately for nonmusicians and musicians because age affected both groups differently. For nonmusicians, recognition accuracy decreased linearly with advancing age for sadness ($r[38] = -.56$, $p < .0001$) and fear ($r[38] = -.52$, $p = .001$), but not for happiness ($r[38] = -.23$, $p = .15$) nor peacefulness ($r[38] = .09$, $p = .57$). This confirms that age was associated with valence-specific changes: decreased recognition of negative emotions and relative invariance for positive ones. For musicians, recognition accuracy did not correlate with age ($r[38] = -.06$, $p = .72$, for sadness; .08, $p = .64$, for fear; $-.004$, $p = .98$, for happiness; and .32, $p = .06$, for peacefulness).

We also computed a Pearson correlation to test the prediction that the length of music training would be associated with enhanced sensitivity to the intended emotions in musicians. The number of years of music training and categorization accuracy pooled across emotions entered this analysis. A positive correlation was found of $r(78) = .33$, $p = .03$. Figure 1 illustrates this significant association.

EFFECTS OF AGE AND MUSICAL EXPERTISE ON THE DISTRIBUTION OF INACCURATE RESPONSES

We analyzed whether the pattern of inaccurate responses varied as a function of age and expertise. For each emotion, an ANOVA was carried out with the non-intended response categories as repeated-measures factor (three non-intended emotions and ambivalent responses), and age and expertise as between-subject factors. For happy music, the interactions between category and the factors age and expertise were *ns*, indicating that the pattern of responses was similar across groups (Age x Category interaction: $F[3, 228] = 1.44$, $p = .23$, $\eta_p^2 = .02$; Expertise x Category: $F < 1$; Age x Expertise x Category: $F < 1$). The same was observed for scary music (Age x Category interaction: $F[3, 228] = 1.45$, $p = .23$, $\eta_p^2 = .02$; Expertise x Category, $F[3, 228] = 1.73$, $p = .16$, $\eta_p^2 = .02$; Age x Expertise x Category, $F < 1$). With respect to peaceful music, the interaction between category, age, and expertise was significant ($F[3, 228] = 3.78$, $p = .01$, $\eta_p^2 = .05$). Post hoc tests revealed that (a) younger nonmusicians responded sad more often than scary ($p < .001$), a difference not observed in the other groups (*p*s > .1), and (b) younger musicians responded happy more often than scary ($p < .001$), a difference also not observed in the other groups (*p*s > .06; Category x Age interaction: $F[3, 228] = 1.24$, $p = .30$, $\eta_p^2 = .02$; Category x Expertise: $F[3, 228] = 1.73$, $p = .16$, $\eta_p^2 = .02$). For sad music, only the interaction between category and age was significant, $F(3, 228) = 4.66$, $p = .004$, $\eta_p^2 = .06$: younger participants misclassified sad music as peaceful less often than middle-aged ones did ($p = .001$; Expertise x Category interaction: $F[3, 228] = 1.03$, $p = .38$, $\eta_p^2 = .01$; Age x Expertise x Category: $F[3, 228] = 1.56$, $p = .2$, $\eta_p^2 = .02$).

CORRELATIONS BETWEEN GENERAL COGNITIVE ABILITIES, PERSONALITY, AND EMOTION RECOGNITION

As shown before (see Method), the four groups were matched in education and gender but they differed somewhat in general cognitive performance and executive control: middle-aged participants had lower scores than younger ones in the MoCA, Raven's matrices, as well as in the Stroop test (incongruous condition); and musicians outperformed nonmusicians in the Stroop test, both baseline and incongruous conditions. Do these differences account for performance in emotion recognition? We computed correlations between global categorization accuracy (score averaged across the four emotions) and scores on the cognitive measures. Correlation coefficients and *p* values are displayed in Table 3. No significant associations were found. This suggests that domain-general cognitive abilities did not determine the recognition of emotions.[4] Another potential

[4] We confirmed that the effects of age and expertise in emotion recognition were not explained by general cognitive abilities by computing ANCOVAs with MoCA, Raven's Matrices and Stroop test as covariates. The interactions of interest, Age x Emotion and Age x Expertise, remained significant, *p*s < .05.

TABLE 3. *Correlations between Cognitive and Personality Measures and Global Accuracy in Emotion Recognition.*

	Emotion recognition accuracy	
Cognitive/personality measure	r(78)	*p*
Montreal Cognitive Assessment	.1	.37
Raven's Advanced Progressive Matrices	.19	.1
Stroop test		
Baseline condition	.15	.18
Incongruous condition	.07	.52
Ten-Item Personality Inventory		
Extraversion	.03	.8
Agreeableness	−.13	.27
Conscientiousness	−.05	.67
Emotional stability	−.17	.12
Openness to experience	.06	.62
Autism Spectrum Quotient	.1	.38
Interest in music	−.16	.17

confound was the musicians' stronger interest in music, but this variable did not correlate with recognition accuracy.

The four groups had similar personality (TIPI) and socio-communicative traits (AQ). We explored possible associations between these traits and emotion recognition, but all analyses yielded non-significant results, including separate analyses by emotion (all *p*s > .1).

MUSIC STRUCTURE CUES AS PREDICTORS OF EMOTION RATINGS

The excerpts communicated emotions through structural cues, and so listeners had to be sensitive to them to succeed in the task. Previous research has already shown that music cues predict responses in emotion recognition tasks (e.g., Balkwill & Thompson, 1999; Gabrielsson & Lindström, 2010; Juslin, 1997, 2000). We computed multiple simultaneous regression analyses to explore how participants of different age and expertise groups relied upon cues to respond. Based on the musical notation, each music stimulus was characterized for tempo (crochet beats per minute), mode (major, minor, or indefinite), tone density (number of melodic events / total duration), pitch range (distance in semitones between the highest and lowest tones of the melody), and pedal (with or without). In addition to these objective measures, scary excerpts were evaluated by a professional musician regarding dissonance, unexpected events, and rhythmic irregularities (five-point scales were used: 1 = consonant, expected, regular; 5 = dissonant, unexpected, irregular; according to the same professional musician, happy, sad, and peaceful excerpts were all consonant, expected, and regular – they were given 1 on these parameters). All these cues varied across the four emotions (*p*s < .05). To keep the set of predictors small and to avoid collinearity, tone density and pedal were excluded because they were strongly correlated with tempo ($r[38]$ = .78 and .71, respectively; *p*s < .001), and unexpected events was excluded because it was strongly correlated with rhythmic irregularities ($r[38] = .89$, $p < .001$). Tempo, mode, pitch range, dissonance, and rhythmic irregularities entered the regression analyses. The dependent variable was the mean raw ratings provided by participants on each emotion scale. Separate regressions were computed for each emotion and group. The main findings are presented in Table 4, where beta weights for each cue and variance explained by the whole model (adjusted R^2) are shown. Responses for the four emotions were predicted by some combination of cues; that is, ratings varied significantly as a function of the presence of structural cues. The proportion of explained variance ranged between .88 (happiness in younger musicians) and .50 (fear/threat in older nonmusicians). Predictors reaching significant beta weights, or their direction (i.e., positive or negative), differed across emotions. Note that no less than two cues yielded significant beta weights for each emotion, showing that participants used a constellation of cues to respond instead of a single cue. The most important predictors of (higher) happy ratings were fast tempo and major mode (larger pitch range was also marginally significant for younger participants); of peaceful ratings, slow tempo and major mode; of sad ratings, slow tempo, minor mode, and decreased rhythmic irregularities (smaller pitch range was also marginally significant for younger nonmusicians); and of fear/threat ratings, minor mode and increased rhythmic irregularities (fast tempo was marginally significant for older musicians). These emotion-specific associations between musical cues and subjective responses are in good agreement with previous descriptions (e.g., Gabrielsson, 2009; Gabrielsson & Lindström, 2010).

Two group comparisons are of particular interest: between younger and older nonmusicians, where valence-specific accuracy differences were observed, and between older musicians and nonmusicians, where the impact of expertise was more evident. The explained variances for younger and older nonmusicians were similar for happy and peaceful ratings, and the relevant cues were the same (tempo and mode, both for happiness and peacefulness; see Table 4). Accordingly, no age effects were observed in recognition rates for these

TABLE 4. *Multiple Regression Analyses on the Predictive Value of Musical Cues for Emotion Ratings in each Group. Values correspond to beta weights and adjusted R^2.*

	Nonmusicians				Musicians			
Age group / Cue	Happy	Peaceful	Sad	Scary	Happy	Peaceful	Sad	Scary
Younger								
Tempo	.59*	−.76*	−.7*	.15	.44*	−.77*	−.5*	.2
Mode	−.34*	−.79*	.26*	.64*	−.6*	−.52*	.56*	.63*
Pitch Range	.16!	.1	−.16!	.03	.15!	−.1	−.13	.03
Dissonance	−.25	.0	.11	.22	−.12	−.03	−.01	.07
Rhyth. Irreg.	.04	−.06	−.23!	.22!	.11	−.2	−.39*	.26!
Adjusted R^2	*.81**	*.66**	*.79**	*.75**	*.88**	*.68**	*.83**	*.60**
Older								
Tempo	.54*	−.72*	−.53*	.19	.63*	−.84*	−.6*	.22!
Mode	−.4*	−.67*	.51*	.47*	−.33*	−.66*	.44*	.5*
Pitch Range	.14	−.09	−.14	.03	.12	−.14	−.08	−.04
Dissonance	−.15	−.05	.01	.09	.11	.03	−.07	.19
Rhyth. Irreg.	−.03	−.13	−.32*	.35!	−.06	−.12	−.24*	.36*
Adjusted R^2	*.81**	*.66**	*.80**	*.50**	*.81**	*.72**	*.81**	*.71**

Note. Rhyth. Irreg. = Rhythmic irregularities
* $p < .05$; ! $p \leq .1$

emotions. For sad and scary ratings, there were differences: in the case of sadness, the predictive strength of the cues was similar across age groups, but rhythmic irregularities was weighted differently (it was a stronger predictor in older than in younger participants); in the case of fear/threat, the pattern of cues was similar, but their predictive strength was significantly lower in older than in younger participants, suggesting that they were used less consistently, i.e., in a less fine-grained way (difference in R^2: −.25; Hotelling/Williams *t*-test, $t(37) = 5.05$, $p < .001$). These results suggest that age-related changes in accuracy for sadness and fear were echoed in differences in the use of structural cues. Regarding expertise, the pattern of predictors yielding significant beta weights was largely similar for musicians and nonmusicians across emotions (Table 4), suggesting that they used the same inference rules. However, the explained variances were higher in older musicians compared to older nonmusicians (+.07, on average), and this may be related to the advantage of musicians in recognition accuracy. The difference was particularly pronounced for scary music (+.21; $t[37] = 6.17$, $p < .001$), which was also the emotion where the expertise related gains in accuracy were larger (+23%).

Discussion

How do we differ in perceiving emotions in music? In this study we determined the roles of age and musical expertise. Four main findings were uncovered. First, advancing age was associated with decrements in the recognition of sadness and fear in instrumental music, whereas happiness and peacefulness remained invariant. Second, the number of years of music training correlated positively with categorization accuracy of the intended emotions, and middle-aged musicians were more accurate than nonmusicians. Third, age and expertise effects were not related to differences in domain-general cognitive abilities, personality characteristics, and interest in music. Fourth, multiple regression analyses revealed that emotion judgments could be predicted from the structural cues of the excerpts, and that the observed effects might be associated with differences in how these cues were used.

AGING AND EMOTION RECOGNITION IN MUSIC

Previous research has consistently shown that aging is associated with decreased accuracy in emotion recognition. Most literature is based on facial expressions (e.g., Calder et al., 2003; Ruffman et al., 2008), but there is evidence of decrements in other domains as well, such as body postures, speech prosody, and nonverbal vocalizations (e.g., Lambrecht et al., 2012; Laukka & Juslin, 2007; Lima, Garrett, & Castro, 2013; Mill et al., 2009; Paulmann et al., 2008; Ruffman et al., 2009; Ruffman et al., 2008). Decrements for sadness and fear are a fairly robust finding in this literature, both in the visual (e.g., Ruffman et al., 2008) and auditory modalities (e.g., Paulmann et al., 2008). Here we focused on emotions expressed in music, which have rarely been investigated. That we also observed age-related declines for sadness and fear indicates that music can undergo the same developmental modulations as other socially relevant stimuli. Our results confirm in a different sample recent findings by Lima and Castro (2011a) and add to Laukka and Juslin's (2007) evidence that older adults (65+ years old) are less accurate than younger ones in categorizing sadness and fear as communicated through expressive cues in performance. Furthermore, we show that these changes are significant in middle-aged adults, a finding that adds to increasing evidence that age operates progressive effects across the adult life span, with differences being discernible early on in the middle years (e.g., Calder et al., 2003; Isaacowitz et al., 2007; Lima & Castro, 2011a; Mill et al., 2009; Paulmann et al., 2008). In contrast to the decrements in negative emotions, sensitivity to happiness and peacefulness remained stable from young to middle adulthood. Relative stability for happiness was previously observed in musical expressiveness as well (Laukka & Juslin, 2007). This has also been found in some studies on other modalities, namely on facial expressions and speech prosody (Calder et al., 2003; Laukka & Juslin, 2007; Williams et al., 2006), but other studies reported decline (Isaacowitz et al., 2007; Paulmann et al., 2008; Ruffman et al., 2009; Ruffman et al., 2008). Therefore, the pattern of stability that we have uncovered for positive emotions for music is not established in other modalities. This might reflect modality-specific mechanisms, i.e., declines for positive emotions may be less apparent in music than in other modalities. Methodological constraints of previous work may also play a role. Most aging studies use an unbalanced number of negative and positive emotions, with happiness often as the only positive emotion, and this undermines conclusions regarding valence differences. A strength of our design is the inclusion of a similar number of positive and negative emotional qualities. Nevertheless, in future studies it will be valuable to include a more diverse range of positive emotions in order to clarify whether the stability obtained here for happiness and peacefulness reflects a general valence effect or is specific to these two emotions (i.e., not generalizable across all positive emotions). This might be feasible, as music is a privileged medium to examine finer grained positive emotions: it is particularly effective in communicating them and positive responses predominate in music listening (e.g., Juslin et al., 2010; Juslin & Västfjäll, 2008; Sloboda & Juslin, 2010). Note that sadness might not always be a negative emotion in music, as it is in other contexts (e.g., Zentner, Grandjean, & Scherer, 2008). Listeners usually do not avoid listening to sad music and can even experience pleasure in response to it (e.g., Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2010; Vieillard et al., 2008). Nevertheless, sad excerpts in our study were at least relatively more negative than peaceful and happy ones. An independent sample of 32 listeners ($M = 33.3$; $SD = 12.2$; range = 18 - 56) judged happy and peaceful music as similarly pleasant in a 10-point valence scale (z-transformed ratings, 0.5 and 0.3, respectively; $p > .30$), and sad and scary excerpts were considered unpleasant (-0.14 and -0.66, respectively; fear was considered more unpleasant than sadness, $p < .01$). Thus, the emotions that underwent age-related effects are those that were rated as more unpleasant.

To understand the mechanisms that underlie age-related changes in emotion recognition, a first step involves establishing whether they are primary in origin or a consequence of general factors such as cognitive losses or personality traits. In this study, consistent with the literature on neurocognitive aging (e.g., Grady, 2012; Salthouse, 2009), middle-aged participants performed worse than younger ones in measures of general cognitive functioning and executive control. However, no relation was found between these abilities and emotion recognition, nor did we find a relation with personality and socio-communicative traits. Thus, we show for the first time that age may affect how we recognize emotions in music in a specific, direct manner. As for hearing acuity, a self-report measure indicated that there were no differences between age groups. Although a more fine-grained and objective measure could have revealed subtle age-related decrements in hearing thresholds, it is unlikely that these would be the origin of changes in emotion recognition: they would predict more general effects across emotions, not selective changes for negative vs. positive emotions. The notion that changes in the recognition of musical emotions can occur beyond cognitive and sensory losses confirms and extends findings for speech prosody (Mitchell, 2007; Orbelo et al., 2005), facial expressions (Keightley et al., 2006; Ruffman et al., 2008; Sullivan & Ruffman, 2004), and body postures (Ruffman et al., 2009). In these modalities, it has been suggested that neural deterioration in structures subtending emotion processing, or top-down controlled processes towards positivity, might explain age-related changes. Neural deterioration is a plausible account for our results as well. Investigating neural structures is outside the scope of this study, but there is evidence of linear structural reductions in the volume of the amygdala throughout the adult life span (Curiati et al., 2009; Giorgio et al., 2010; Mu, Xie, Wen, Weng, & Shuyun, 1999; Peelle, Cusack, & Henson, 2012; Walhovd et al., 2005; Walhovd et al., 2011), and neuropsychological research using the same stimuli and task as the present study has shown that the integrity of this structure is critical for the perception of fear and sadness in music (Gosselin et al., 2005, 2007). This would also be in agreement with the hypothesis put forward by Cacioppo et al. (2011) that deterioration in the amygdala might be the origin of dampened responses to negative information at older ages (but for arguments claiming relatively preserved amygdala functioning, see Mather & Carstensen, 2005; Reed & Carstensen, 2012). In the same line of reasoning, it is possible that the stability observed for the positive emotions is related to the relative preservation of basal ganglia structures (e.g., Williams et al., 2006; but see, Raz et al., 2003), which have been shown to be involved in responses to pleasant music (e.g., Koelsch, Fritz, Cramon, Muller, & Friederici, 2006; Lima et al., 2013; Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007; Salimpoor et al., 2011). Alternatively, the pattern of selective decrements for negative vs. positive emotions might result from controlled regulatory mechanisms. According to the socioemotional selectivity theory, as a function of decrements in time horizons, advancing age would lead to enhanced motivation to heighten cognitive resources towards positive information (e.g., Carstensen & Mikels, 2005; Reed & Carstensen, 2012). The majority of research conducted within this framework includes participants older than the middle-aged ones studied here, but some studies used continuous samples, including the middle years, and they indicate that the positivity effect emerges progressively and linearly throughout the adult life span (e.g., Charles, Mather, & Carstensen, 2003; Kisley, Wood, & Burrows, 2007; Williams et al., 2006). Note, though, that this account would predict a close association between general cognitive abilities, namely cognitive control, and heightened attention towards positive information (Knight, Seymour, Gaunt, Baker, Nesmith, & Mather, 2007; Mather & Knight, 2005), which we failed to find. In general, performance on cognitive control did not correlate with performance on emotion recognition (see Results), and additional correlation analyses on older participants and for specific emotions also did not yield significant results (*p*s $> .20$). Future studies combining behavioral measures with functional and structural brain imaging techniques will be critical to clarify the relative contribution of neural deterioration and controlled processing to age effects in emotion recognition in music. Such studies will also throw light on the differences that we observed in how younger and older participants relied on music structural cues to respond. For happy and peaceful responses, the relevant cues did not change with advancing age, but for sadness and fear older participants weighted some cues differently and were significantly less consistent than younger ones. This might be a consequence of neural deterioration, but it can be linked to top-down processes as well: it is possible that older participants implement a controlled disengagement of music cues associated with negative emotions. Furthermore, in the future it may be insightful to complement ratings of specific emotions with ratings of broader affective dimensions, specifically arousal and valence. Vieillard et al. (2012) observed that older adults did not perceive arousal and valence in the same way younger participants did, and that they also did not use these properties as cues to group music excerpts in an implicit free emotion categorization task.

An additional finding was that age-related effects were not detected in musicians. Previous research on how environmental factors can influence cognitive aging suggests that expertise in a specific domain may attenuate age-related changes for well-practiced tasks that are highly related to that domain (for a review, see Kramer, Bherer, Colcombe, Dong, & Greenough, 2004). Because an important part of musicians' training and professional practice throughout life concerns the expression and perception of musical emotions, this intensive and permanent practice might offset normative age-related trajectories, at least within the age range covered by the present study; it is critical to maintain sensitivity to positive, as well as to negative emotional expressions in music, in order to be effective in expressing and interpreting them. This incidental result deserves to be followed-up in future studies, which will benefit from covering the full range of the adult life span.

MUSICAL EXPERTISE AND EMOTION RECOGNITION IN MUSIC

Two findings indicate that music training bolsters emotion recognition in music. First, years of music training correlated positively with recognition accuracy. This suggests that learning music gradually fine-tunes mechanisms underlying musical emotions, as assessed in an explicit emotion recognition task. Second, middle-aged musicians as a group were more accurate than age-matched nonmusicians in categorizing the four emotions. We showed for the first time that the effects of expertise cannot be explained by differences in socio-educational background, general cognitive abilities, and personality characteristics. The correlation between length of practice and accuracy extends previous preliminary results by Lima and Castro (2011a) for less trained participants, by Livingstone et al. (2010) for musical emotions portrayed by both structural and expressive cues, and by Bhatara et al. (2011), who focused on the expressive features of timing and amplitude.

Further support for the notion that musical practice influences emotion processing in music comes from a recent study by Dellacherie et al. (2011). These authors found that musical experience affects both behavioral and psychophysiological responses to dissonance in music. Music training was associated with more unpleasant feelings and stronger physiological responses to dissonance, as assessed by skin conductance and electromyographic signals. Resnicow et al. (2004) failed to find effects of training, possibly because their design did not have enough statistical power – they included only three stimuli per emotion and the number of trained participants was not reported. That younger musicians, as a group, were not more accurate than nonmusicians was unanticipated. We can speculate that this null finding was due to sampling error, or that the stimuli and task were insensitive to group differences in this age cohort; or that there are indeed no differences between these two younger groups. The fact that expertise effects differed between age cohorts highlights the importance of examining different groups when drawing general inferences about how music training modulates cognition.

It is possible that the effect of expertise is small and difficult to detect. This might explain why Bigand et al. (2005) obtained highly consistent and similar responses to music from trained and untrained participants. In a review of studies on the effects of musical expertise, Bigand and Poulin-Charronnat (2006) concluded that the effects of expertise on music processing are typically small, particularly in light of the huge differences in training that usually exist between groups; this would be evidence that many musical abilities are acquired through exposure and do not require explicit training. Our results add to the evidence that music training is not a prerequisite to perceive emotions in music high accuracy and consistency: all our participants identified the four intended emotions with high agreement rates. This consistency was obtained with stimuli that were short, unfamiliar, all played in the same genre and timbre, and expressing emotions exclusively through music compositional cues. Moreover, as indicated by the regression analyses, participants were able to effectively use these cues to differentiate the emotions. By claiming that learning music impacts on emotion recognition we mean to highlight the plasticity of the system and not to argue that it requires training to be robust and highly effective.

How does music training sharpen the recognition of emotional qualities in music? Musicians, because of their extensive implicit and explicit practice with musical emotions, might develop finer-grained, readily accessible categories to respond to emotion cues in music. Finding that they were more consistent than nonmusicians in using structural cues to respond accords well with this hypothesis. Barrett and colleagues (Barrett, 2006, 2009; Lindquist & Barrett, 2010) have suggested that individual differences in emotional responses and experience might reflect differences in the *granularity* of emotion concepts, which could be trained. According to this theoretical framework, individuals with higher emotional granularity are more precise, specific, and differentiated in categorizing affective states, while those with low granularity experience and describe emotions in a more global and less differentiated way. Higher emotional granularity could be achieved through training and practice, just like wine and X-ray experts learn to perceive subtle differences that novices are unaware of. It is possible that music training contributes to increase the granularity of emotion concepts for music.

Conclusion

This study showed that the experiential factors age and musical expertise modulate how we recognize emotions in music. Advancing age was associated with decreased responsiveness to the musical emotions of sadness and fear, as it happens with facial expressions and speech prosody. By contrast, responsiveness to the positive emotions of happiness and peacefulness remained invariant. We also observed that music training is associated with more accurate categorization of musical emotions, thus adding to the evidence on the interplay between music experience and music perception. Both age and expertise effects were independent of domain-general cognitive and personality differences, suggesting that they are primary in origin. Regression analysis revealed that they might be linked to differences in how efficiently music structural cues are relied upon. These findings add to the emerging evidence on individual differences in emotion processing (e.g., Cremers et al., 2010; Hamann & Canli, 2004; Koch et al., 2007). Mechanisms supporting emotion recognition in music are robust, but also dynamic and variable: they are changed by life experiences.

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Appendix

DISTRIBUTION OF RATINGS (0-9) FOR EACH INTENDED EMOTION IN YOUNGER AND OLDER NONMUSICIANS AND MUSICIANS

	Ratings across response categories							
	Nonmusicians				Musicians			
Age group/ excerpt type	Happy	Peaceful	Sad	Scary	Happy	Peaceful	Sad	Scary
Younger								
Happy	**7.6 (0.2)**	1.6	0.2	0.2	**7.2 (0.4)**	1.7	0.2	0.2
Peaceful	2.8	**5.5 (0.4)**	4.6	0.2	4.3	**4.9 (0.5)**	3	0
Sad	0.4	3.3	**7.4 (0.2)**	2.1	0.4	4.6	**7 (0.3)**	0.9
Scary	1	0.4	3.7	**7.1 (0.3)**	0.8	1.2	3.5	**5.2 (0.5)**
Middle-aged								
Happy	**6.7 (0.5)**	2.1	0.6	0.4	**7.4 (0.3)**	1.6	0.6	0.6
Peaceful	3.9	**5 (0.5)**	2.7	0.4	2.9	**5.2 (0.4)**	3.2	0.4
Sad	1.5	3.9	**5.5 (0.5)**	0.5	0.7	4.4	**6 (0.3)**	1.3
Scary	1.8	0.6	2.9	**3.7 (0.4)**	1.5	0.8	2.8	**5.3 (0.4)**

Note. Diagonal cells in bold indicate ratings on the excerpts' intended emotion. *SE*s are presented in parentheses.